

The Status of CO₂ EOR in Texas

CO₂ for EOR as CCUS:

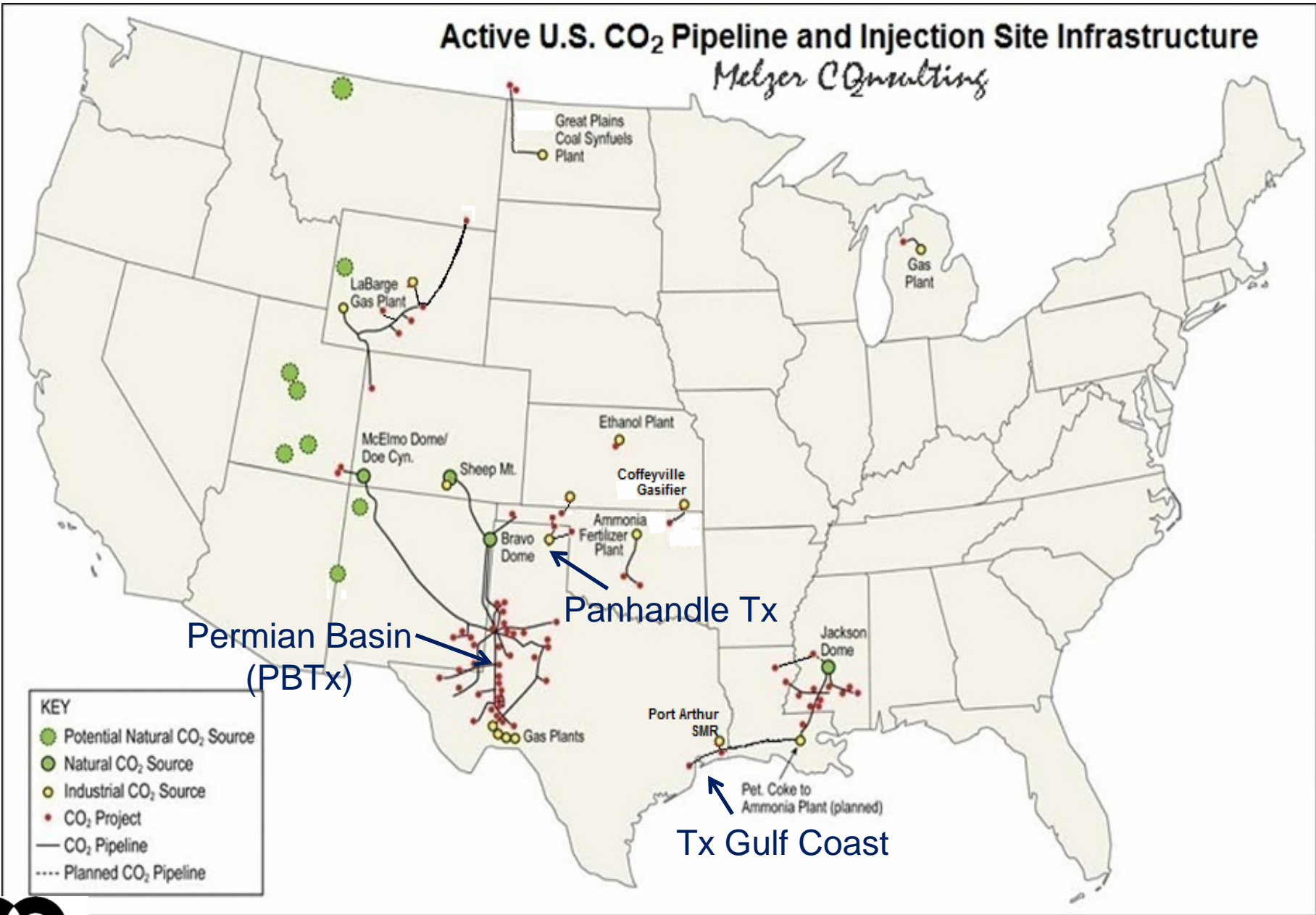
A Collaborative Symposium on CO₂ EOR

Rice University

November 19, 2013

Active U.S. CO₂ Pipeline and Injection Site Infrastructure

Melzer CO₂ Consulting



KEY

- Potential Natural CO₂ Source
- Natural CO₂ Source
- Industrial CO₂ Source
- CO₂ Project
- CO₂ Pipeline
- Planned CO₂ Pipeline

Permian Basin
(PBTx)

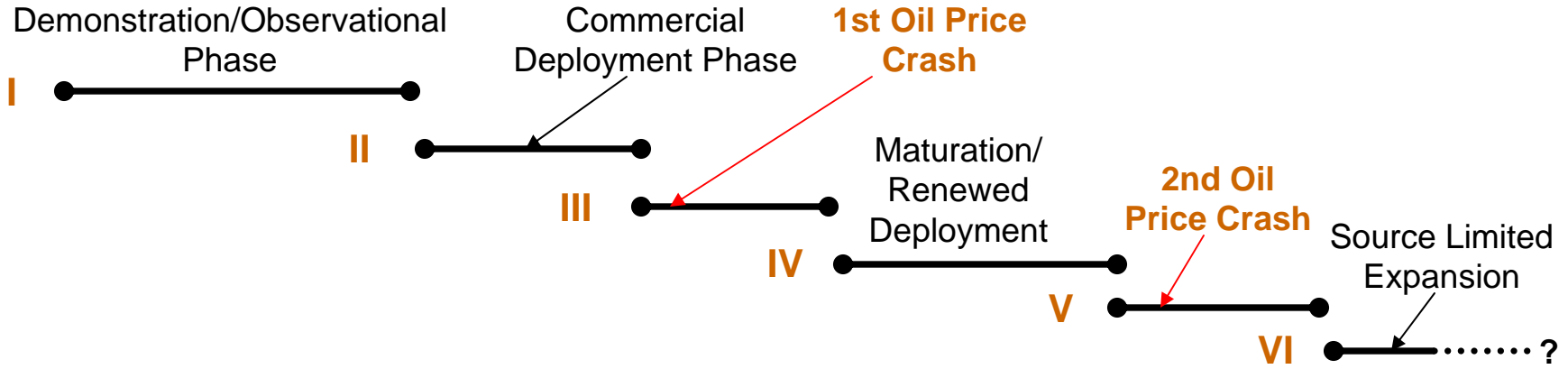
Panhandle Tx

Tx Gulf Coast

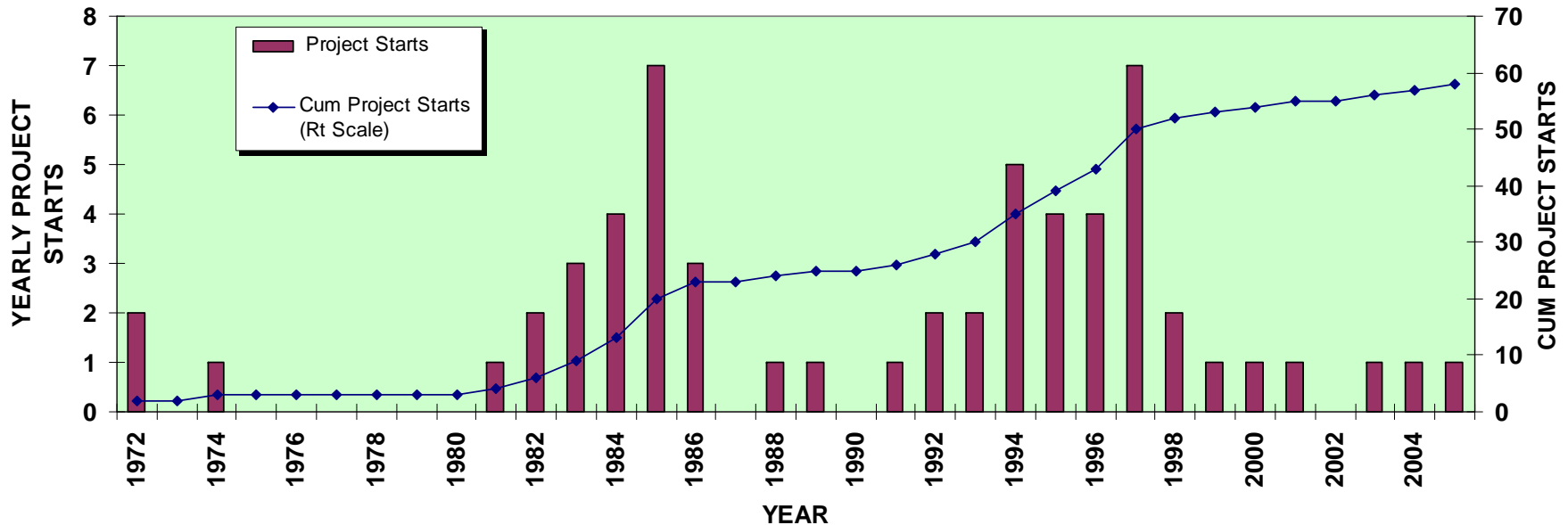


THE PHASES OF CO₂ ENHANCED OIL RECOVERY

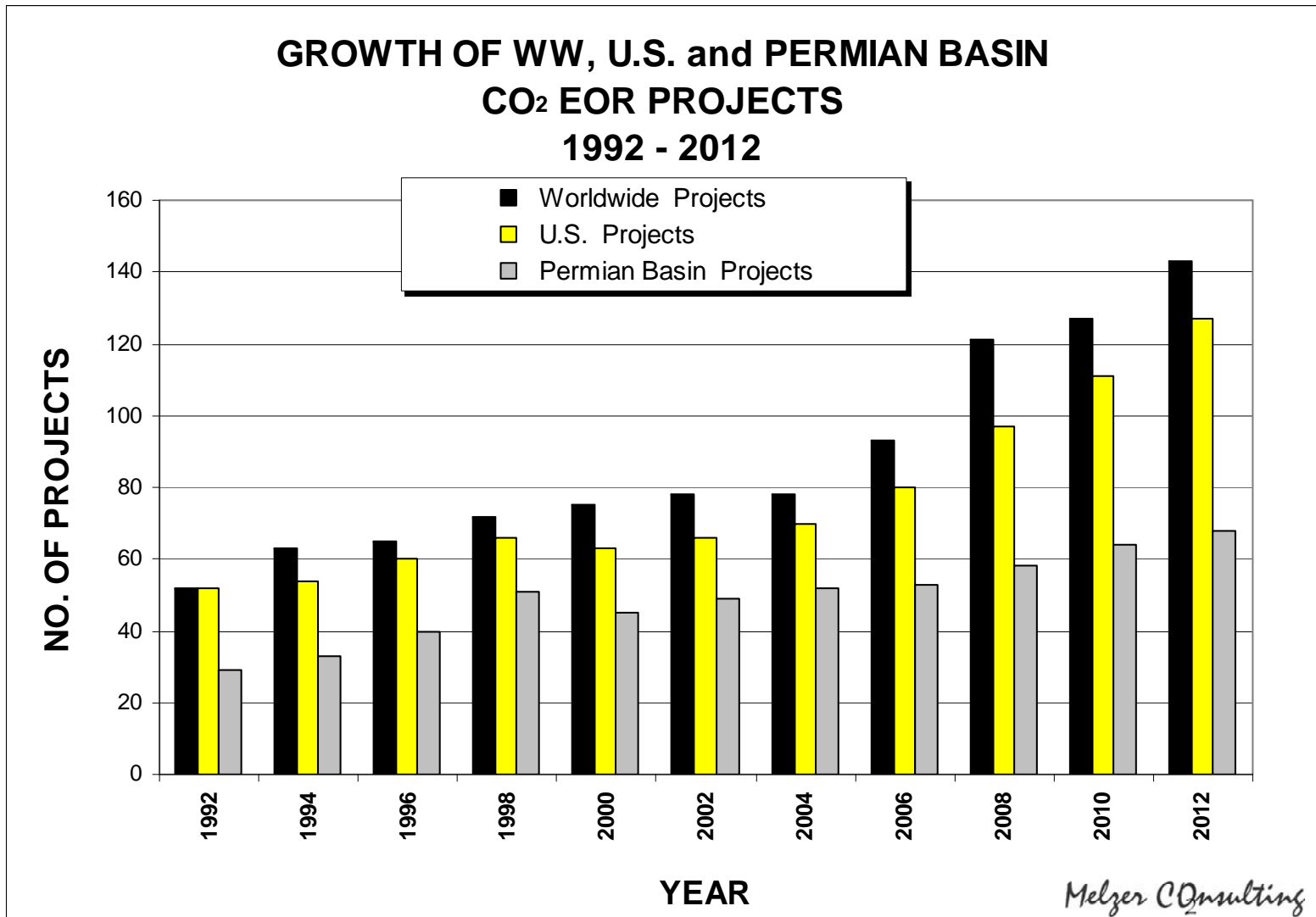
as Referenced to the Permian Basin Region of the U.S.



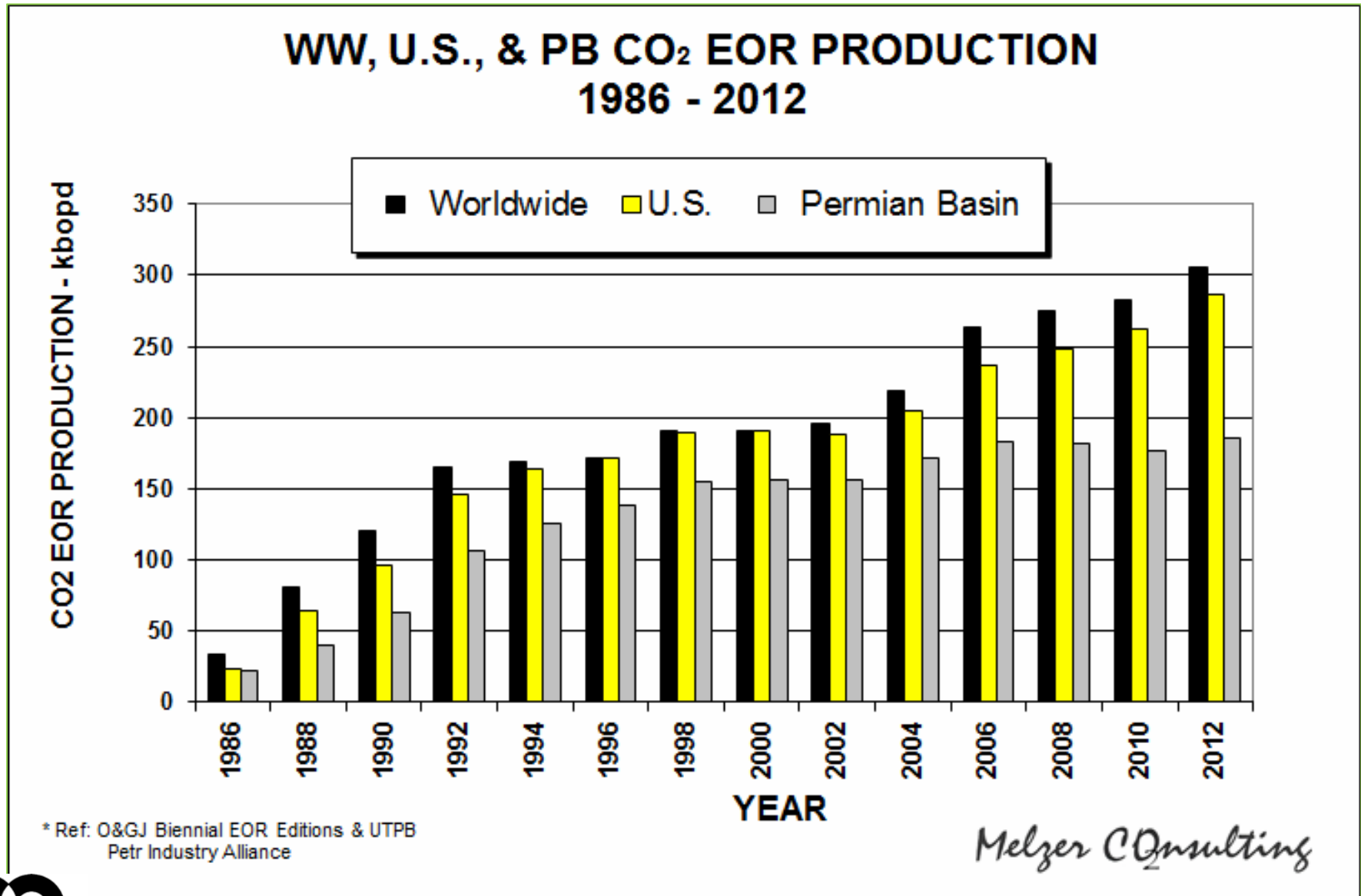
PERMIAN BASIN CO₂ PROJECT STARTS



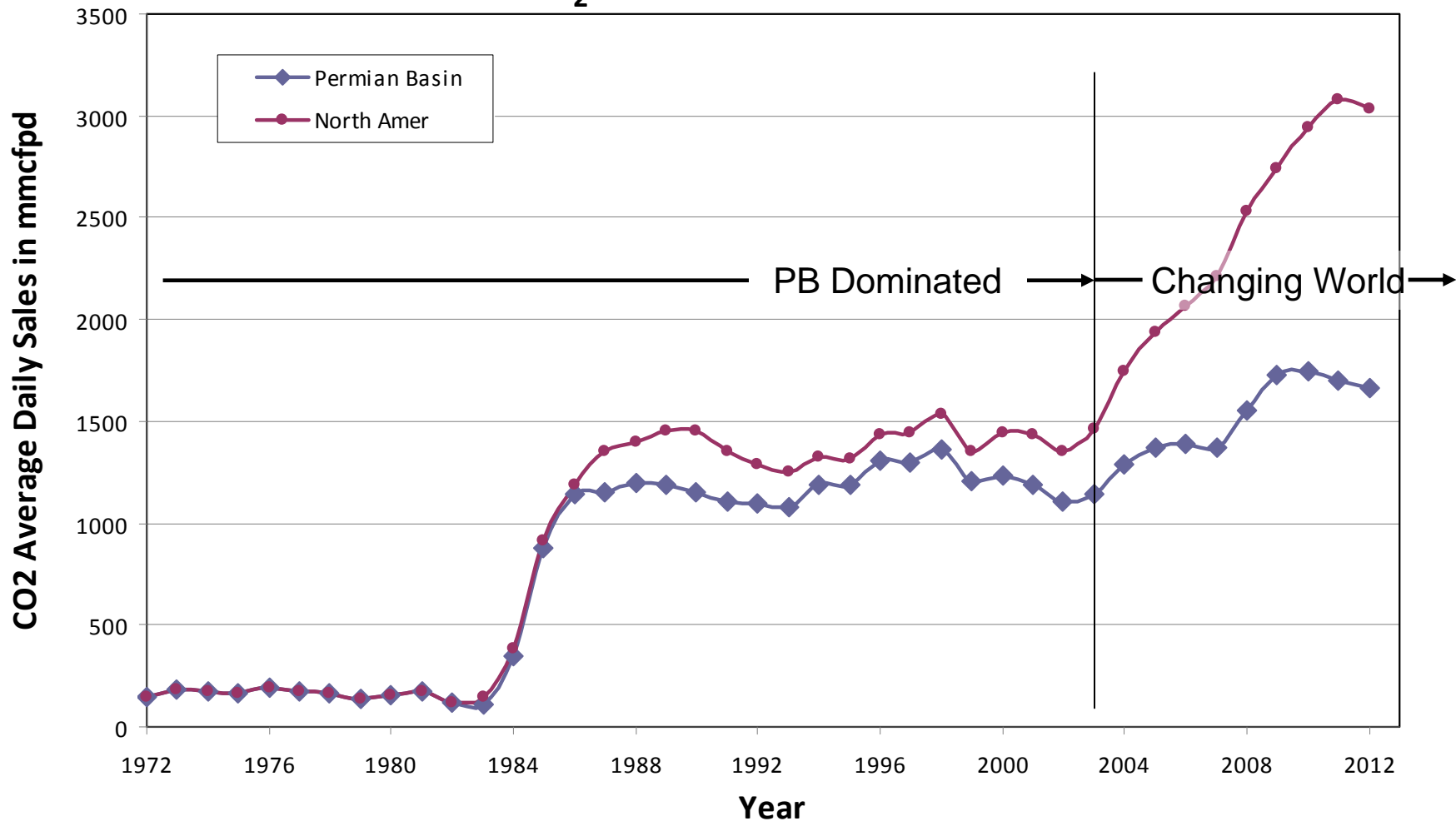
Current Situation – CO₂ EOR Projects



Current Situation – CO₂ EOR Production



Historical CO₂ Sales: U.S. and Permian Basin

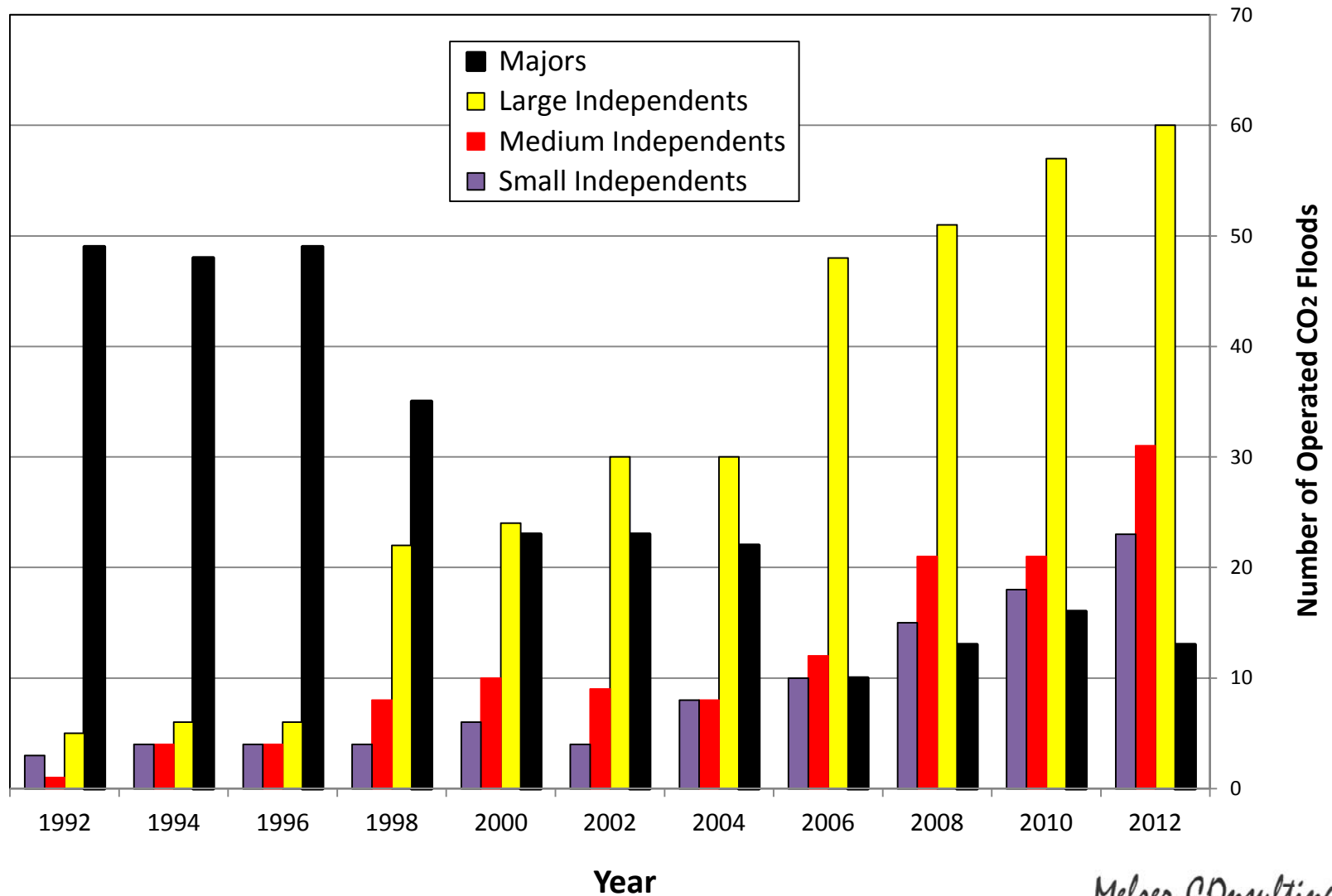


New Texas CO₂ Floods

<u>Field/Unit</u>	<u>Operator</u>	<u>CO₂ Vols (mmcfpd)</u>	<u>EOR Vols (bopd)</u>
North Perryton	Chaparral Energy	20	2500
Albert Spicer Unit	Chaparral Energy		
Booker Trosper Unit	Chaparral Energy		
Gramstorff Unit	Chaparral Energy		
Farnsworth Unit	Chaparral Energy		
Oyster Bayou	Denbury Resources	180	9000
Hastings, West	Denbury Resources		



CO₂ Flooding Operators Trends: Company Size over Time

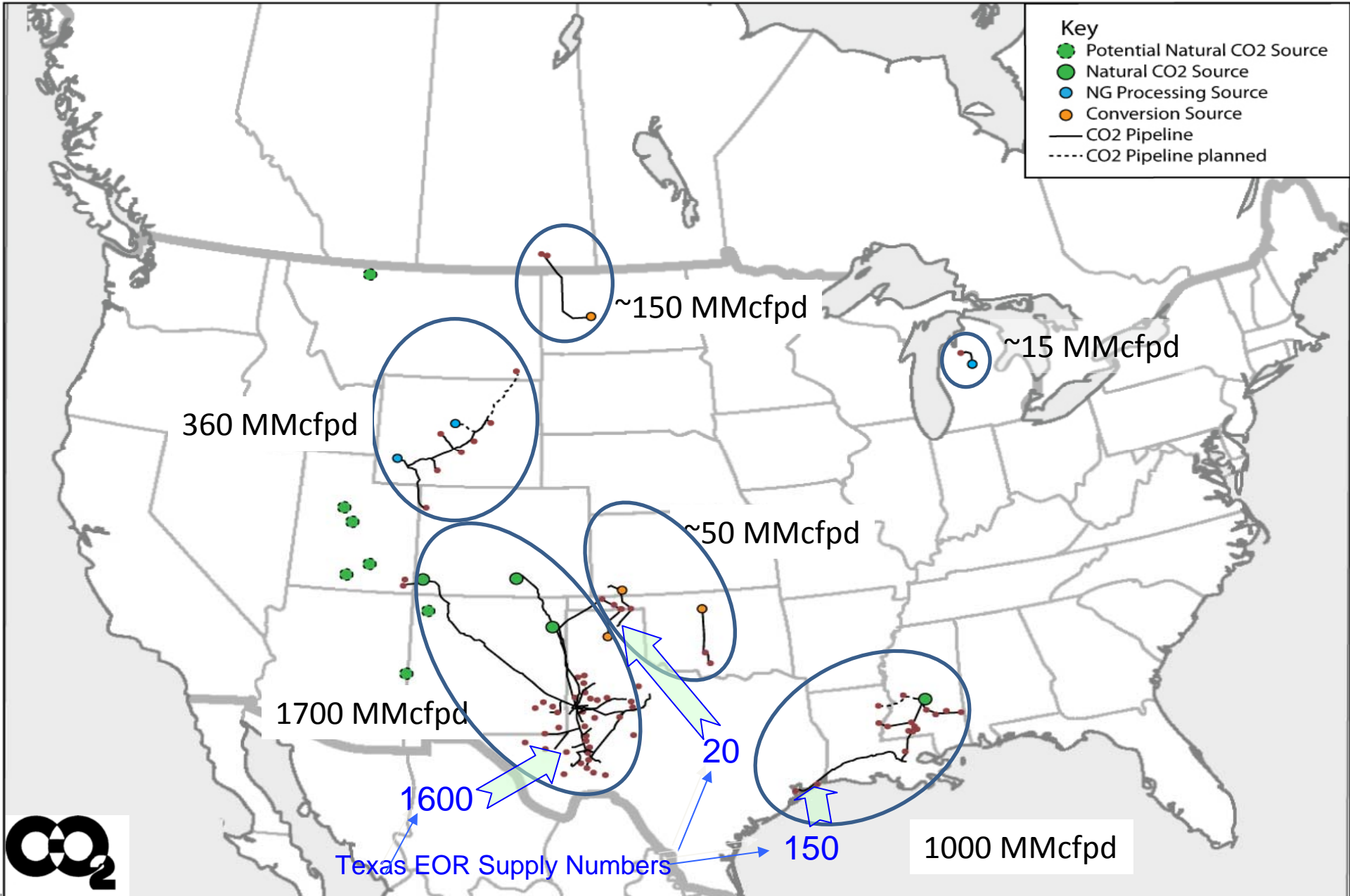


CO₂ EOR Supply in 2013



Key

- Potential Natural CO₂ Source
- Natural CO₂ Source
- NG Processing Source
- Conversion Source
- CO₂ Pipeline
- - - CO₂ Pipeline planned



Texas EOR Supply Numbers

1000 MMcfpd

The Permian Basin CO₂ EOR Infrastructure

SHEEP MOUNTAIN

OPERATOR	W.I.%
OXY	50
EXXONMOBIL	50
RESERVES:	< 0.2 TCF
DELIVERABILITY:	30MMCF/D

BRAVO DOME

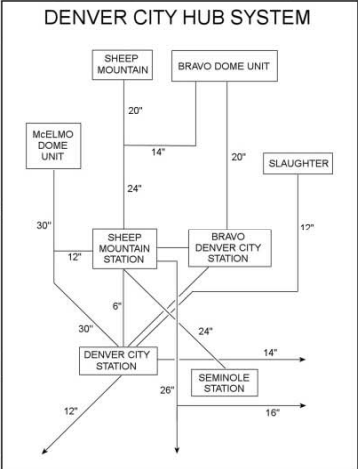
OPERATOR	W.I.%
OXY	75
KINDERMORGAN	11
HESS	10
OTHERS	4
RESERVES:	2 TCF
DELIVERABILITY:	260 MMCF/D

McELMO DOME

OPERATOR	W.I.%
KINDERMORGAN	44.5
EXXONMOBIL	43.5
CHEVRON	5.0
OTHERS	7.0
RESERVES:	10 TCF
DELIVERABILITY:	12 BCF/D

PIPELINE KEY

- KINDER MORGAN CO₂ PIPELINES/LATERALS
- OXY SHEEP MOUNTAIN PIPELINE
- PETROSOURCE PIPELINE
- TRANSPETCO PIPELINE
- HESS ROSEBUD PIPELINE
- TRINITY CO₂ LLANO & WEST TEXAS PIPELINES
- WELLMAN PIPELINE
- COMANCHE CREEK PIPELINE
- OXY PERMIAN BRAVO PIPELINE
- RESOLUTE McELMO CREEK PIPELINE
- ADAIR PIPELINES
- EXXON/MOBIL MEANS PIPELINE
- SLAUGHTER & ESTE PIPELINES
- ⋯ CENTURY PLANT PIPELINES

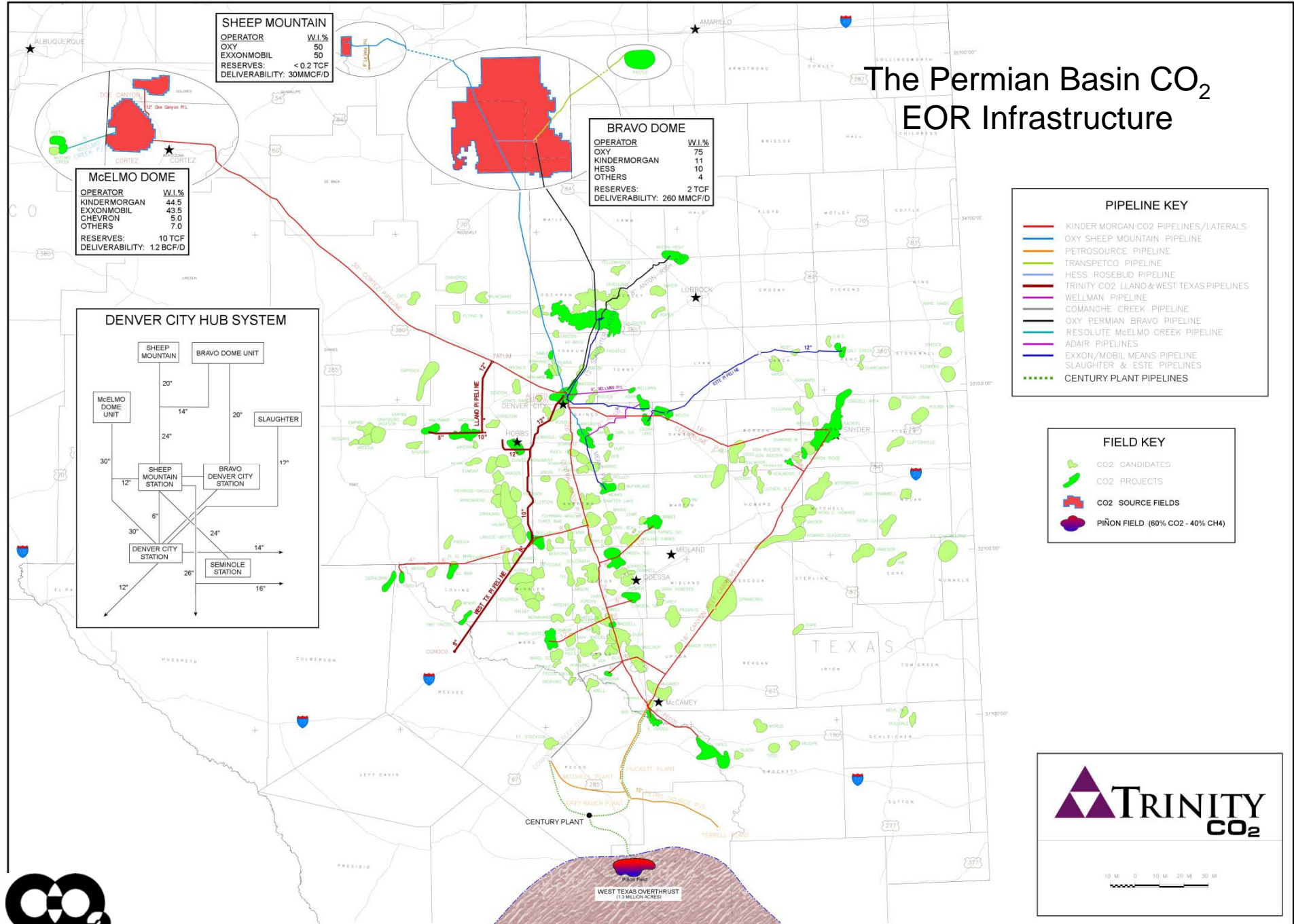


FIELD KEY

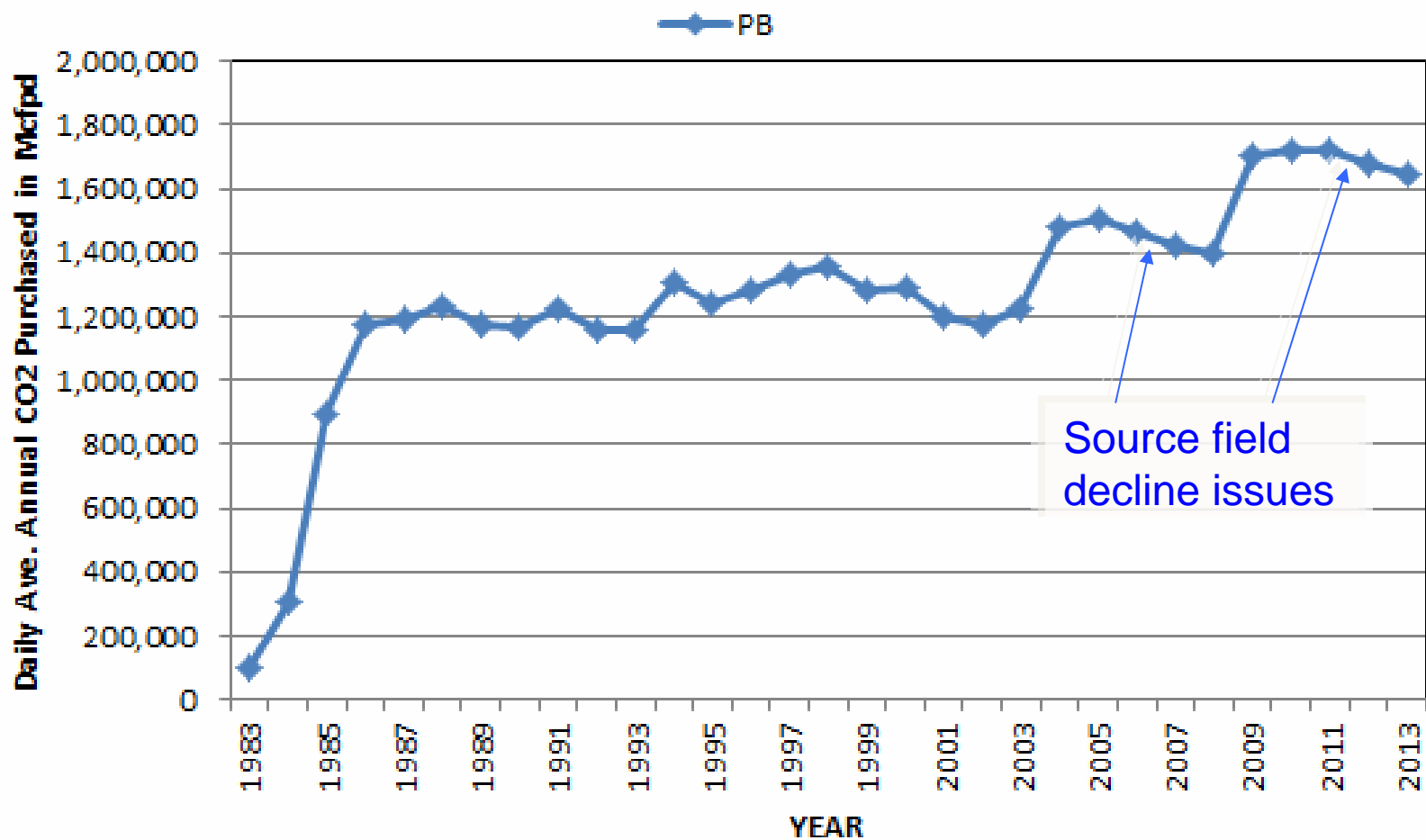
- CO₂ CANDIDATES
- CO₂ PROJECTS
- CO₂ SOURCE FIELDS
- PIÑON FIELD (60% CO₂ - 40% CH₄)

TRINITY
CO₂

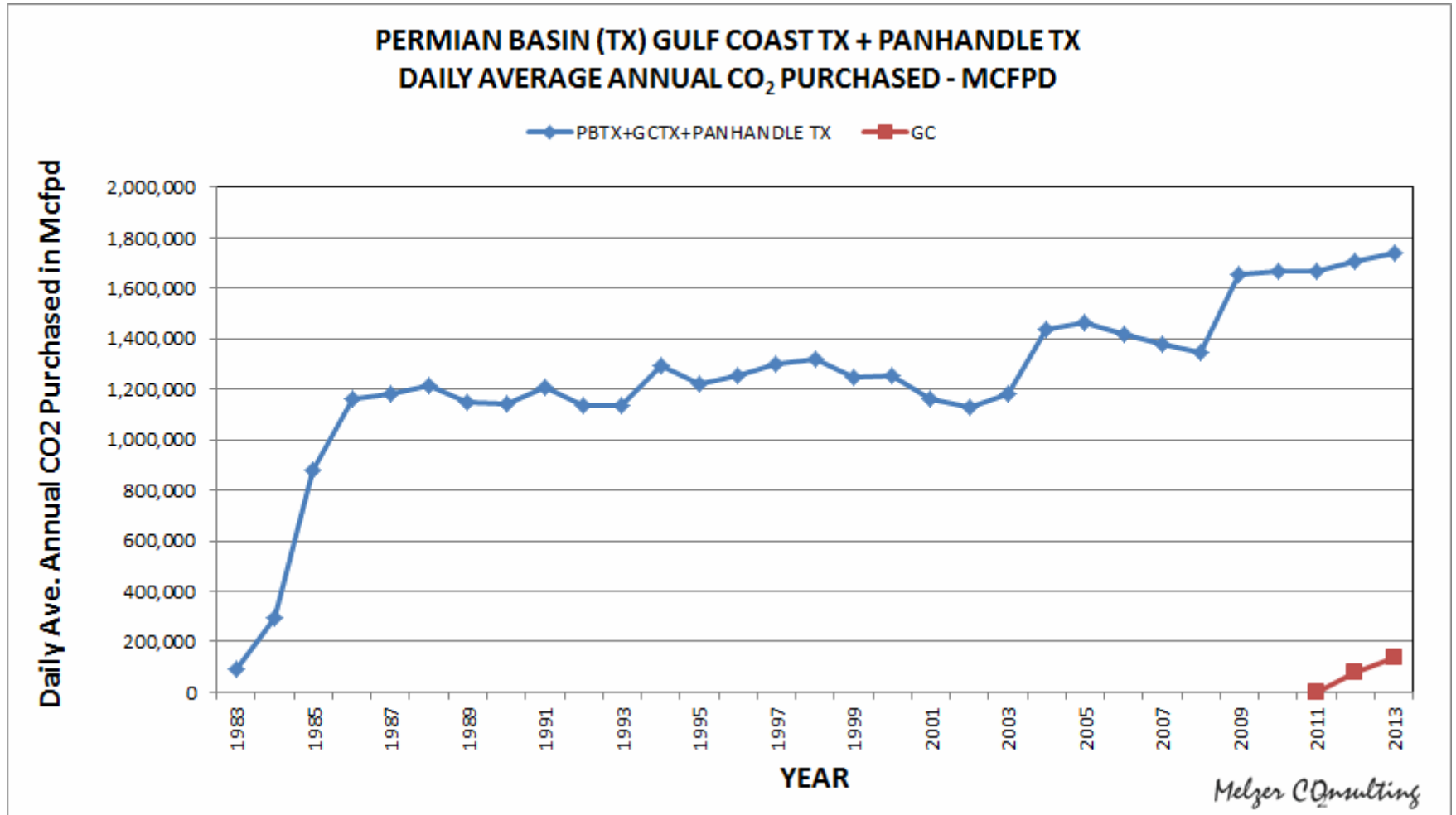
10 MI 0 10 MI 20 MI 30 MI



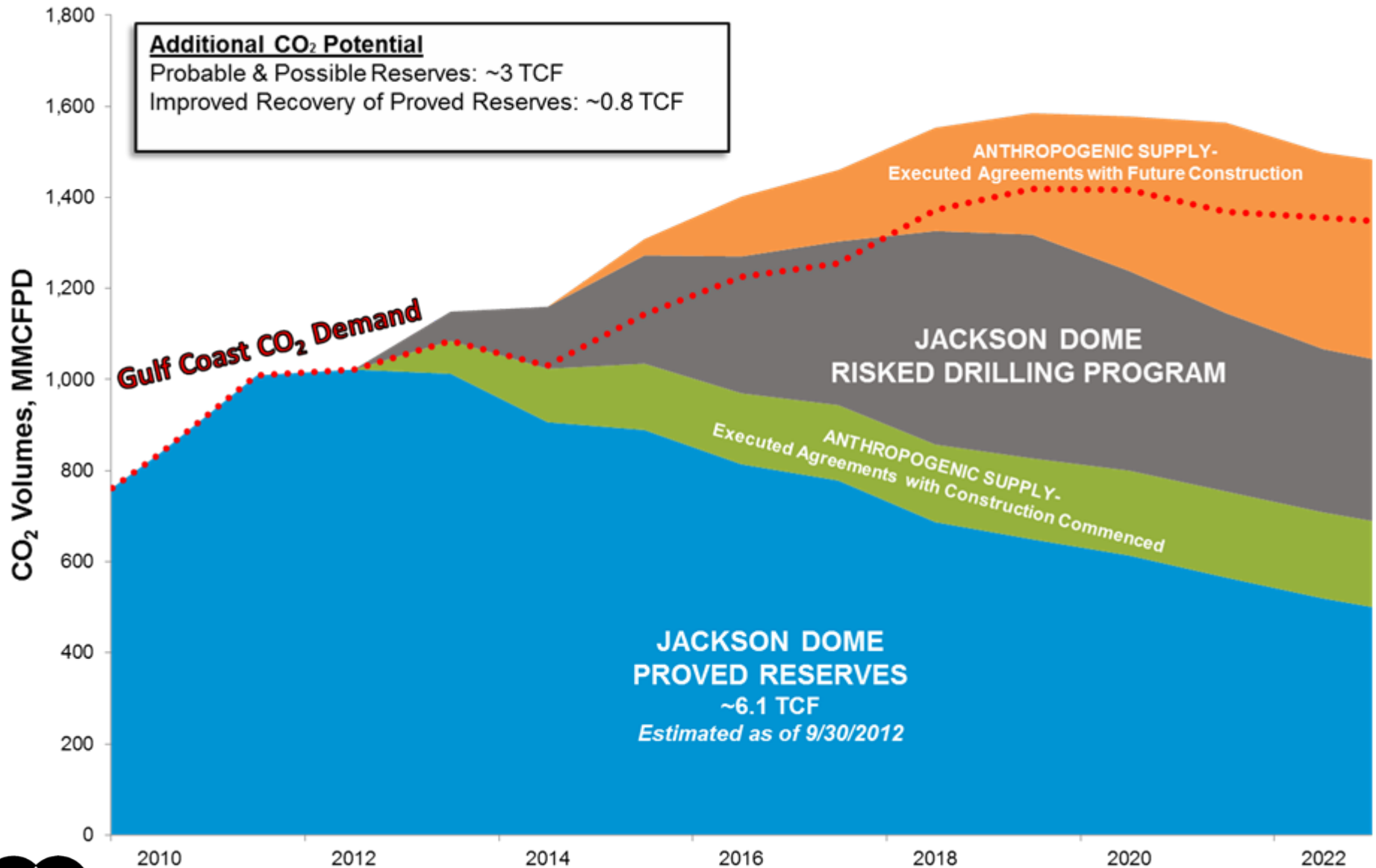
PERMIAN BASIN DAILY AVERAGE ANNUAL CO₂ PURCHASED - MCFPD



CO₂ EOR PURCHASES ALL OF TEXAS



Gulf Coast Supply



Note: Forecast based on internal management estimates. Actual results may vary.

A Closer Look at CO₂ EOR Technology



CO₂ EOR Toolbag

Categories of Very Successful CO₂ Floods

- Geometry Category
 - Horizontal Miscible Floods (w/ Vertical Wells)
 - Vertical Miscible (Gravity Assisted) Floods
 - Vertical Immiscible (Gravity Assisted Floods)
- Lithology Category
 - Dolomites
 - Sandstones
 - Limestones
- Oil Type Category
 - Light Oils (Gravity > 25° API)



CO₂ EOR Toolbag

Categories of Moderately Successful CO₂ Floods

- Geometry Category
 - Horizontal Flooding of Immiscible Reservoirs
- Oil Type Category
 - Medium Gravity Oils
- Lithologies
 - Tripolites
 - Marls
- Secondary (Depressured Reservoir) CO₂ Floods



CO₂ EOR Toolbag

Categories of “Challenged” CO₂ Floods

- Geometry Category
 - Dipping Reservoirs – Miscible or Immiscible
 - Horizontal Injection Wells
- Age
 - “Pre-law” Wells
- Lithologies
 - Fractured
 - Compartmentalized (Vert or Hor)



CO₂ EOR Toolbag

Categories of “Emerging Technology” CO₂ Floods

- Residual Oil Zones
- Medium Gravity Oils
- Beating the Conformance Issues
 - Fractured Reservoirs
 - Highly Variable Permeability Sections in Reservoirs

Will also be covered in the next talk:
Dr. Trentham



Residual Oil Zones (ROZs)

- Industry Has Very Successfully CO₂ Flooded Mature Waterfloods
- Mother Nature Can Waterflood Also
- Can We Successful CO₂ Flood MNWs?



Mother Nature Can Waterflood Too!!

A Multiple Stage Tectonics Framework

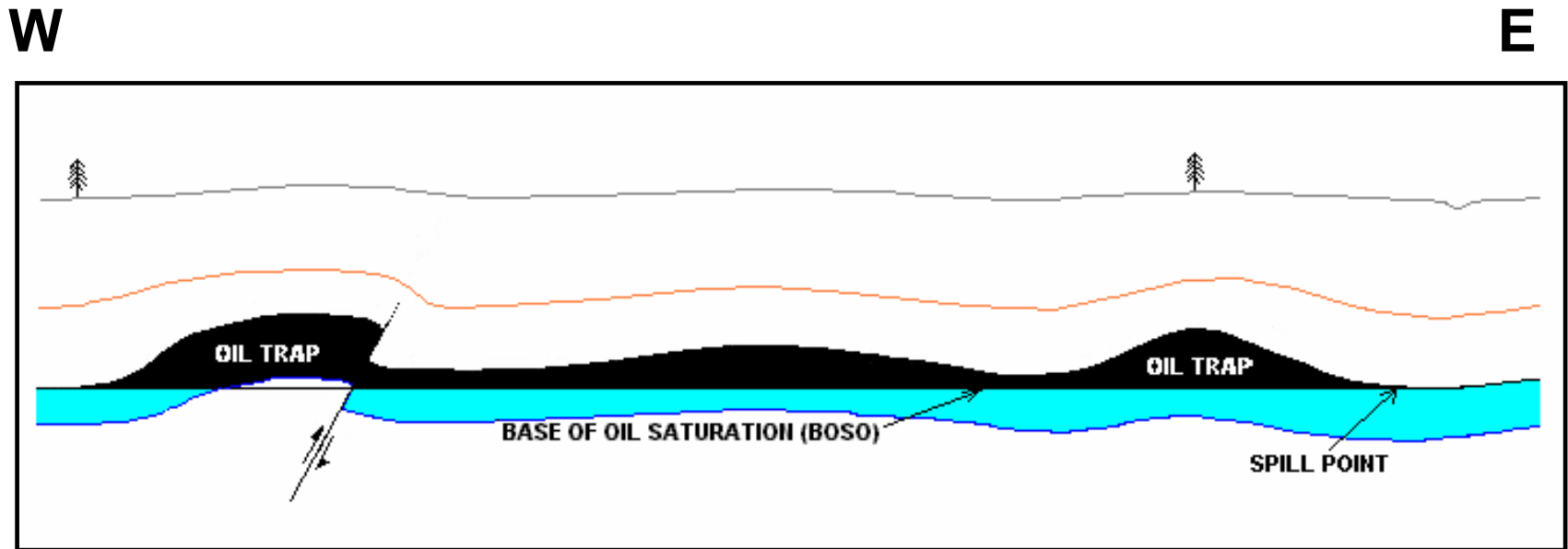
- 1) Deposition
- 2) First Stage Tectonics: Basin Subsidence, Hydrocarbon Generation and Migration to a Trap
- 3) Second Stage Tectonics (Moving Oil Around):
 - I – Basinal Tilt,
 - II – Breached Seal,
 - III – Uplift and Lateral Sweep



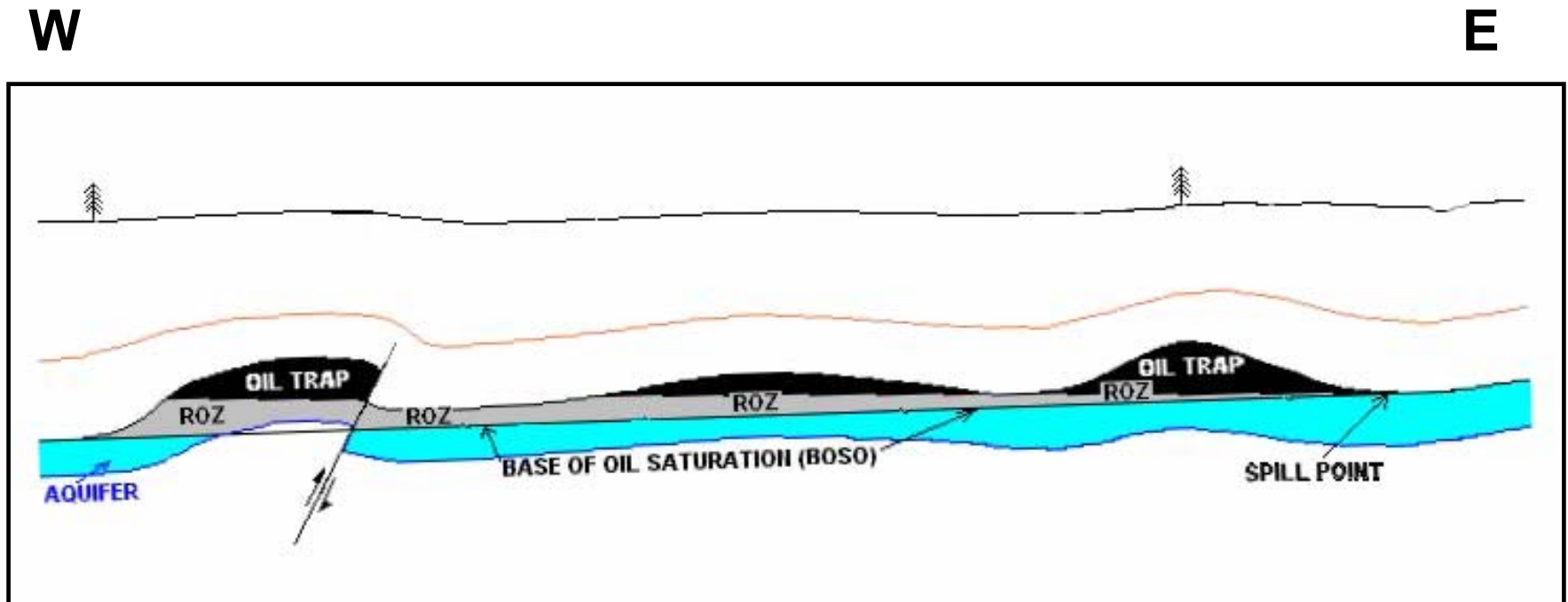
The Science of Residual Oil Zones



Original Oil Accumulation Under Static Aquifer Conditions (A Hypothetical Example)



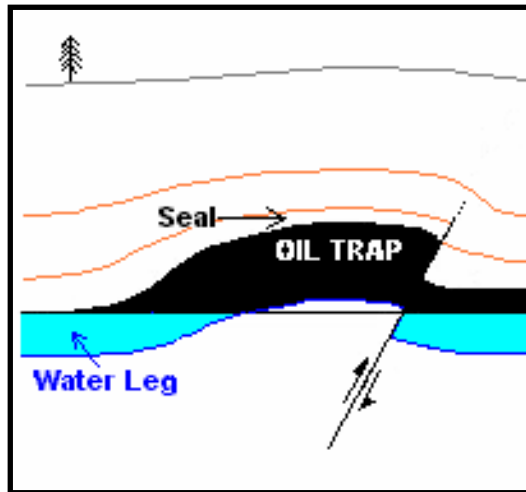
Original Accumulation Subject to a Westward Regional Tilt & Forming a ROZ



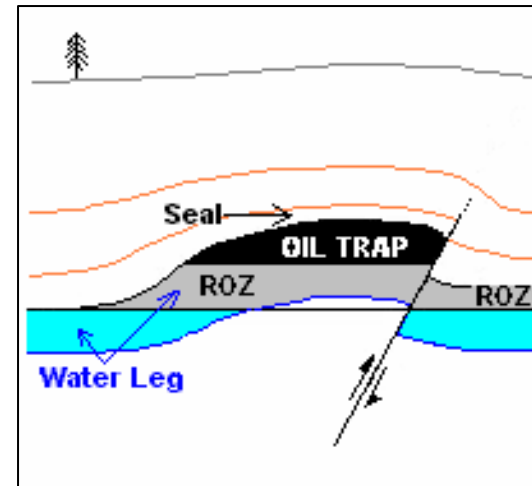
TYPE 1 ROZ

Original Accumulation with a Breached then Repaired Seal & Forming a ROZ

ORIGINAL

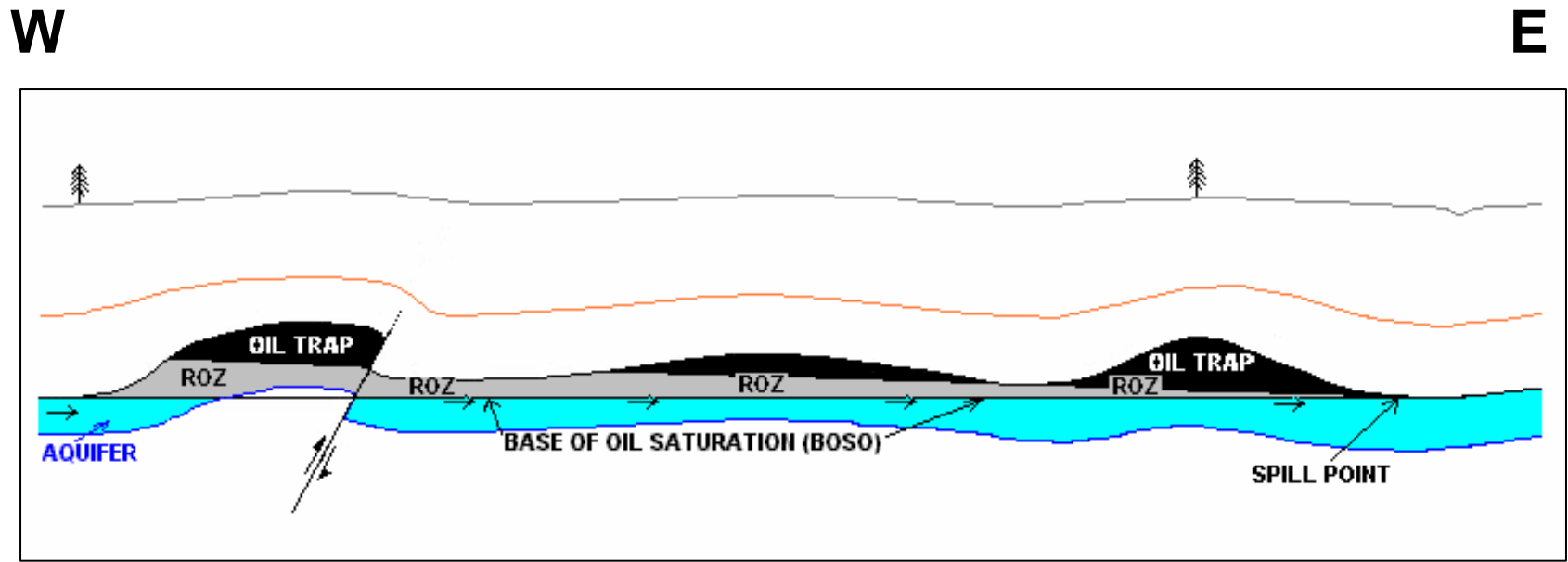


POST BREACH



TYPE 2 ROZ

Change in Hydrodynamic Conditions, Sweep of the Lower Oil Column, Oil/water Contact Tilt, and Development Of The Residual Oil Zone



TYPE 3 ROZ

Note: Tilted Oil / Water Contact



Dr. Trentham's Talk (Next) Will
Continue this ROZ Subject



KEY TEXAS CO₂ EOR EVENTS

ROZ Exploitation

- 1992: Shell Initiates Commingled MPZ & Transition Zone Sweet Spot Flood at Denver Unit (DU) to 150 feet below OWC**
- 1997: Altura Expands Transition Zone Project at DU to Phase I Area**
- 1997: Hess Initiates Commingled MPZ & ROZ pilot at Seminole San Andres Unit (SSAU)**
- 2005: Hess Initiates Dedicated ROZ pilot at SSAU**
- 2006: Melzer Consulting Publishes DOE Report on the Origins of ROZs and Emerging Commercial Importance**
- 2008: Hess Begins Field-wide Deployment of ROZ Project at SSAU**
- 2008: ARI et al Publish DOE Report on the ROZ Resource Base**
- 2009: UTPB and ROZ Team, Funded by the Research Partnership to Secure Energy for America, Working to Better Explain the Origins and Distributions of ROZs in the Permian Basin**



Concluding Thoughts and Observations

1. ***CO₂ EOR has emerged as the Fastest Growing EOR Method and this is without Consideration for Value in CO₂ Storage*** – 127 U.S. Projects Currently Making 350,000 bopd
2. ***Residual Oil Zones are Emerging as Viable CO₂ EOR Opportunities in the Permian Basin.*** Twelve Active Projects Underway Making >11,000 bopd.
3. ***Growth in CO₂ EOR is Limited by Supplies of Available and Affordable CO₂.*** Current Supplies (3.1 bcfpd {65 million tons per year} are 75% Pure Natural and 25% Industrial by-product)
4. ***ROZ Opportunities Need to be Evaluated in Other Regions/Basins.*** Is the Permian Basin Really Unique?
5. ***Convergence of Storage Objectives Can Change the Pace of Deployment of CO₂ EOR in Dramatic Fashion***



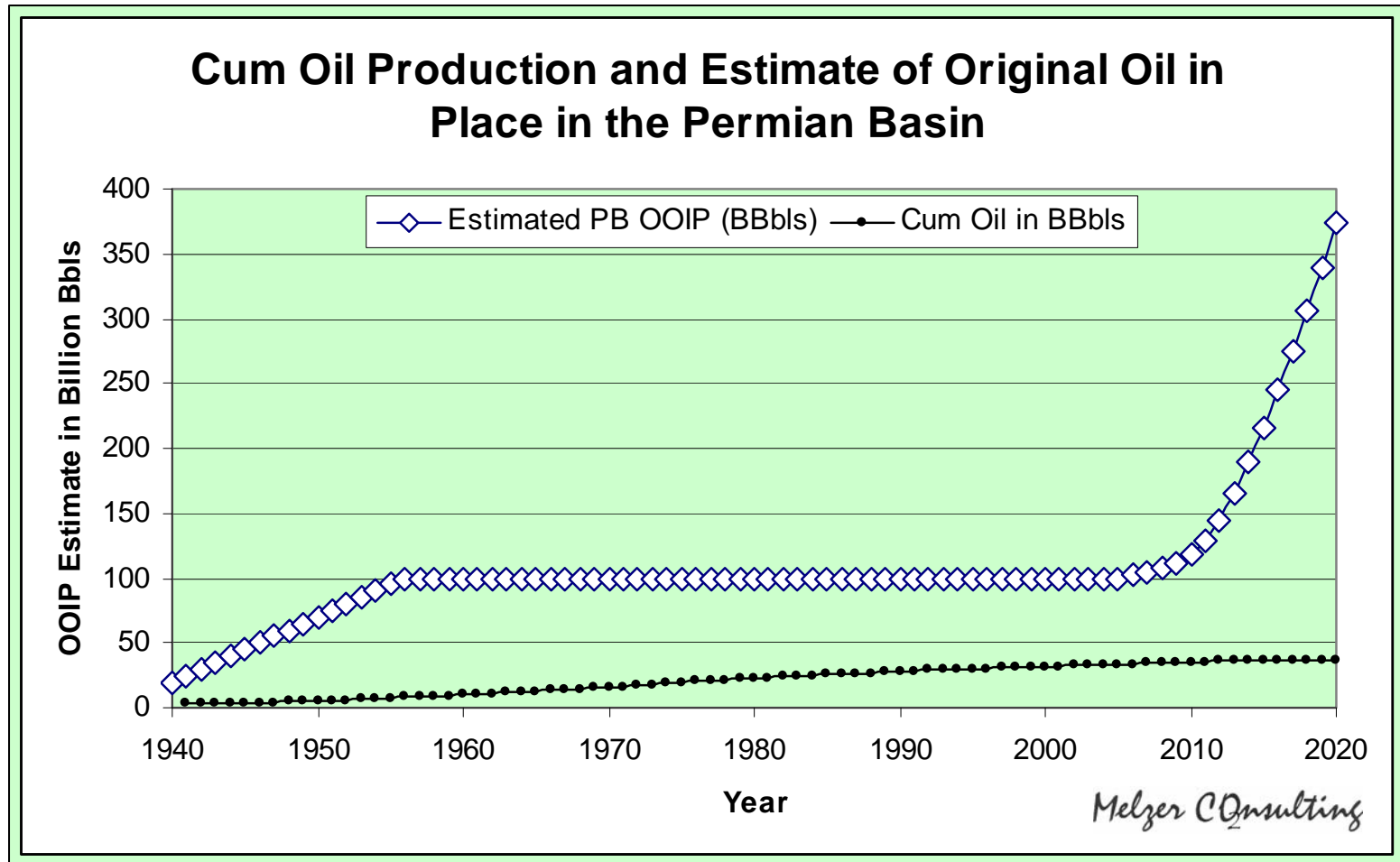
Questions?



A Final Set of Thoughts on CO₂ EOR Technology



Renewed Growth of PB Production and New Evolving Estimates of OOIP



Are We Comfortable with This?

Either as an Industry or as the State of Tx

